The Status Of Three Species Of Marine-Estuarine Birds In The Interior Of Florida:

Attraction to Phosphate Mines of the Central Peninsula

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ABSTRACT

I documented and analyzed the inland status of three species of marine-estuarine birds that have rarely occurred in the interior of Florida, based on observational data and information from recovery of banded birds. All but one occurrence are from the 20th century. Brown Pelicans *Pelecanus occidentalis* have increased throughout the interior since the mid-1980s, and although they occur most frequently in the central peninsula, the influence of phosphate mines was negligible. Their increase, based on observational data, involved a shift in the seasonal distribution from winter and spring to predominantly spring. The increase of Royal *Sterna maxima* and Sandwich *S. sandvicensis* Terns was restricted to phosphate mines in the interior of the central peninsula, where most other observations also occurred. The seasonal distribution of Royal Tern, based on observational data, involved a shift from winter prior to the late 1980s to also include spring and autumn since the late 1980s, when phosphate mines influenced their occurrence during both seasons. Recovery of most banded Royal Terns and Brown Pelicans occurred during winter, possibly indicating greater mortality during that season In contrast to Royal Tern, the seasonal distribution of Sandwich Tern was concentrated in late summer and autumn. The probable reasons for the change in the inland status of the three species in Florida include their response at phosphate mines to the availability of early to mid-successional clay settling ponds with sandy shorelines and other open water habitats. The status of marine-estuarine birds in the interior of Florida is subject to a number of influences; the importance of the Lake District of the central peninsula is emphasized

INTRODUCTION

Located in the central peninsula of Florida, the Lake District is a water-dominated landscape unique in southeastern North America, with the largest concentration of natural lakes in the eastern United States south of the Great Lakes (Brenner et al. 1992). The development of the pebble-phosphate mining industry beginning in the 1930s in central Florida has added to this landscape diked, raised clay settling ponds, with and without vegetation depending on successional stage (Blakey 1973, Bromwell 1982, Rushton 1983). These artificial freshwater impoundments increased in size later, especially with the accelerated growth of phosphate production since the early to mid-1960s (Bromwell 1982, Rushton 1983, Riekerk et al. 1991). The impoundments now cover about 60% of the mined landscape in central Florida, although land reclamation laws passed in 1975 mandate that these impoundments are converted to terrestrial habitats (Rushton 1983, Riekerk et al. 1991). Thus, each impoundment that is productive wildlife habitat for open-water birds depends upon how long the filling stage lasts (reception of water with 2–5% solid clay slurry), usually anywhere from approximately 2–10 years. Two other man-made open freshwater habitats occur at phosphate mines. After the dragline was introduced in 1920 (DeVall and DeVane 1949, Blakey 1973), many unreclaimed mine pits became deep-water finger lakes or water-filled pits with barren shorelines which were and still remain one of the dominant landforms on phosphate mines (Schones and Humphrey 1987). "Land-and-lakes" (gently contoured lands interspersed with series of deep-water lakes) were added when voluntary reclamation efforts by mining companies began in 1949 (Blakey 1973). For example, dredge pits at the old Saddle Creek phosphate mine just outside Lakeland, Polk County, were converted to the "land-and-lakes" landscape (Blakey 1973); this site became a county park in 1961. Phosphate mining in central Florida has recently expanded to Manatee and Hardee Counties (IMC-Agrico homepage). Because of its high quality, most pebble phosphate is still mined in southwest Polk (and eastern Hillsborough) County (DeVall and DeVane 1949, Blakey 1973, Layne et al. 1977, Schones and Humphrey 1987), where it began in the mid-1880s. In contrast to central Florida, the much smaller phosphate-mining industry in the

northern peninsula did not begin until the early 1970s (Maehr 1981, Schones and Humphrey 1987).

The Lake District (and Lake Okeechobee) does influence movements to the interior of Florida of marine-estuarine birds that breed along the Gulf and Atlantic Coasts of the state, regardless of observer biases (*cf.* Least Tern *Sterna antillarum*; McNair 2000a). Least and Gull-billed *S. nilotica* Terns have nested regularly at man-made sites (including phosphate mines) in the interior of Florida (Maehr 1984, McNair 2000a). Man-made habitat changes have also helped non-breeding populations of Laughing Gull *Larus atricilla* and Black Skimmer *Rynchops nigra* to increase, and both species have become numerous at phosphate mines in the central peninsula over the last two decades (Robertson and Woolfenden 1992, Stevenson and Anderson 1994, C. Geanangel pers. comm.). Thus, phosphate mines in the interior of Florida have influenced the inland status of four species of marine-estuarine birds that breed along the coast. Excluding shorebirds from consideration, the remaining three marine-estuarine species that breed along the coast of Florida (Brown Pelican *Pelecanus occidentalis* and Royal *S. maxima* and Sandwich *S. sandvicensis* Terns) have rarely occurred in the interior, but an increasing number of occurrences has accumulated over the past several decades, especially in the central peninsula. Although a large proportion of non-breeding inland occurrences of some marine-estuarine and other marine birds has been attributed to storms (Robertson and Woolfenden 1992), an analysis has been lacking, except in the case of Magnificent Frigatebird *Fregata magnificens* (McNair 2000b).

I document and analyze the inland status of three species of marine-estuarine birds (Brown Pelican, and Royal and Sandwich Terns) that have rarely occurred until recently in the interior of Florida to address three issues: 1) Have these three species really increased in the interior of Florida or does an apparent increase only represent an increase in observer effort? 2) What is the significance of any change in status and how may habitat changes influence the status of these three species in the interior of the central peninsula, especially at phosphate mines? 3) Have tropical cyclones influenced the occurrence of these three species in the interior of Florida?

METHODS

I restricted my analyses to three species of marine-estuarine birds that breed along the coast of Florida (Clapp et al. 1982, 1983, Clapp and Buckley 1984, Robertson and Woolfenden 1992, Stevenson and Anderson 1994). I omitted other species of marine-estuarine birds heretofore mentioned and which breed along the coast of Florida because I could not distinguish many non-breeding from regular breeding occurrences of Gull-billed and Least Terns in the interior, and non-breeding occurrences of Laughing Gull and Black Skimmer have become so numerous they are impossible to analyze with the methods employed herein.

I conservatively defined the interior of Florida to exclude tidewater areas and the immediate coast. For example, the occurrence of a coastal bird at Lake Maggiore, Pinellas County, or in the bypass canal that extends inland from Palm River in Hillsborough County is not considered to be from the interior of Florida. I obtained observational data on inland occurrences of Brown Pelicans and Royal and Sandwich Terns from Howell (1932), Clapp et al. (1982, 1983), Robertson and Woolfenden (1992), Stevenson and Anderson (1994), *Audubon Field Notes* and its successors *American Birds* (cf. Loftin et al. 1991), *Field Notes*, and *North American Birds*, the field observations section of the *Florida Field Naturalist*, the archives, specimens, and photographs at Tall Timbers Research Station (TTRS), specimens from other collections, and unpublished observations of various individuals (see Acknowledgments). Additional information was obtained for Brown Pelican in Nicholson (1927, 1951) and Smith and Goguen (1993) and for Royal Tern in Lohrer (1984) and Fellers (1988). I excluded inland occurrences of Brown Pelicans from Lake Okeechobee since 1986 because they have become more or less resident since the late 1980s and breeding began there in 1991 (Smith and Goguen 1993, Anderson and Baker 1994). I also excluded several suspect reports for Royal Terns in the interior of Florida because I believe these birds were misidentified. I categorized each observation for all three species in the interior of Florida into one of four geographic regions as defined by Robertson and Woolfenden (1992).

Observational data substantially departed from a normal distribution. Consequently, I used non-parametric tests, although analogous parametric tests on log-transformed numbers yielded similar results. For each species, I tested for differences between counts at and away from phosphate mines, then among geographic regions, then among years.

I obtained recovery data from the Bird Banding Laboratory, Patuxent Wildlife Research Center, United States Geological Survey and published sources, Longstreet and Davis (1936), Longstreet (1945) and Smith and Goguen (1993) for Brown Pelican, and Lohrer (1984) for Royal Tern. I examined all banding records for internal consistency and rigorously excluded any record if I was not certain that the bird was recovered within the interior of Florida. Because information on the total number of pelicans and terns banded prior to 1955 is not available (Schreiber and Mock 1988, K. Klimkiewicz pers. comm.) and the number of recoveries is low, I did not adjust recovery data for banding effort. I used three age-classes (immatures, subadults, adults) for each species. Immatures are nestlings or fledged birds less than or equal to 12 months old. Subadults are about 1–4 years old (Brown Pelican) or circa 1–2 years old (terns). Adults are 5 years (Brown Pelican) or 2 years (terns) (Schreiber and

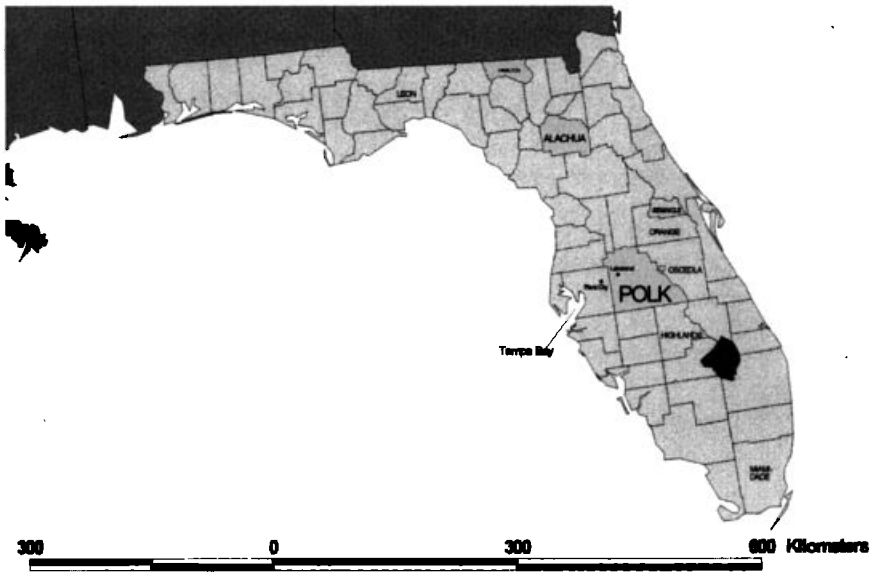

Figure 1. Important geographical locations in Florida that are cited in the text, including names of counties from each of the four regions where observations of three marine-estuarine species were most numerous.

Schreiber 1983; cf. Blokpoel et al. 1984).

I examined the tracks of tropical cyclones in the North Atlantic Ocean using several sources (Neumann et al. 1981, annual reports in *Monthly Weather Review* for data from 1981–1995 and in *Weatherwise* from 1996–1999) to determine which species occurrences were associated with tropical cyclones. The broad category of tropical cyclones included tropical depressions and subtropical cyclones with winds ≥ 63 km (39 mph). I defined a marine-estuarine bird to be cyclone-assisted if the bird was reported within 500 km of the storm track and within 3 days before to 10 days after the storm's landfall or offshore passage (*cf.* Tuck 1968, Fussell and Allen-Grimes 1980, McNair and Gore 1998). These associations should be reliable because almost all observations of the three species in the interior of Florida that were associated with tropical cyclones occurred within 4-5 days after the passage of the storm (*cf.* DeBenedictus 1986). For additional clarification, I also examined hurricane season summaries of North Atlantic tropical cyclones in *Monthly Weather Review*, weather data in *Storm Data* (since 1959), and *Daily Weather Maps* (since 1969).

RESULTS

Observational Data

Brown Pelican and Royal and Sandwich Terns have occurred over 40 times each in the interior of Florida, with Brown Pelican the most numerous and Sandwich Tern the least numerous of the three species (Table 1). Over 70% of the total observations for each species in the interior were from the central peninsula (χ^2 probability < 0.01 for each species, tests excluding regions without observations). For each geographic region, observations have centered on the following counties or city-county entities, listed in order of decreasing abundance for central Florida only (Fig. 1): Panhandle (*Leon*), North Florida (*Alachua*), Central Florida (*Polk, Highlands, Orange, Osceola,* and *Seminole*), and South Florida (*Miami-Dade*). South Florida was the only region where observations were not concentrated in a county or city-county entity that contained numerous large lakes.

Table 1. Number of observations of three species of marine-estuarine birds in the interior of Florida, and the percentage of these species within four geographic regions.

Species	Number of Observations	Percentage (%) of Observations			
		Panhandle	North	Central	South
Brown Pelican	122	5	17	71	7
Royal Tern	69	4	15	81	0
Sandwich Tern	41	5	0	90	5

All observations of these three species at phosphate mines in the interior of Florida occurred within the central peninsula at Polk County, where Brown Pelican was the least numerous of the three species (Table 2). The number of observations at phosphate mines as a percentage of the total number of observations throughout the central peninsula and all regions in the interior of Florida was greatest for Sandwich Tern and least for Brown Pelican (Table 2).

Table 2. Number of observations of three species of marine-estuarine birds at phosphate mines in Polk County, and the percentage of these observations of the number throughout the central peninsula and all regions in the interior of Florida.

Species	Number of Observations	Percentage (%)	
	Phosphate Mines	Central Florida	All Regions
Brown Pelican	19	22	16
Royal Tern	31	55	45
Sandwich Tern	32	86	78

The number of occurrences by decade for all three species has increased in the interior of Florida (Table 3). The increase was significant for Brown Pelican (first occurrence in 1910 and first occurrence at phosphate mines in 1987; 88% of occurrences since the 1970s) and Royal Tern (first occurrences in 1887 and 1935 and first occurrence at phosphate mines in 1981; 91% of occurrences since the 1970s). Sandwich Tern also has increased (first occurrence in 1965 and first occurrence at phosphate mines in 1984), especially in the 1990s (73% of all occurrences). The number of birds per occurrence for each of the three species in the interior of Florida did not exceed 2 until the mid- to late 1980s, for Brown Pelican (1986), Royal Tern (1988), and Sandwich Tern (1984).

Table 3. Number of observations of three species of marine-estuarine birds by decade in the interior of Florida.

Species	Decade										Spearman's Rank Correlation	
	<1910	1910	1920	1930	1940	1950	1960	1970	1980	1990	r	P
Brown Pelican	–	4	1	2	0	4	4	10	22	73	0.78	0.01
Royal Tern	1	0	0	2	1	0	2	10	14	39	0.82	0.02
Sandwich Tern	–	–	–	–	–	–	2	4	5	30	na[1]	na[1]
TOTAL	1	4	1	4	1	4	8	24	41	142		

[1] na = not applicable

Counts of Brown Pelican in the interior of Florida away from Lake Okeechobee have reached 20 birds (in Polk County, away from phosphate mines). The number of birds at phosphate mines (median = 1, range = 1–3, n = 19) was not significantly different than the number away from phosphate mines (Mann-Whitney U tests), either compared to throughout the interior of Florida (median = 1, range = 1–20, n = 101; U = 788, $P > 0.20$), only within central Florida (median = 1, range = 1–20, n = 66; U = 473, P = 0.10), or only within Polk County (median = 1, range = 1–20, n = 24; U = 160.5, P = 0.10). The mean number of birds at phosphate mines in Polk County (1.21) was less than in these three regions (range of means: 2.25–3.88). Including or excluding observations at phosphate mines, the number of pelicans in the interior of Florida was not significantly different among the four geographic regions (Kruskal-Wallis tests; including phosphate mines: H = 3.32, $P > 0.25$; excluding phosphate mines: H = 4.64, P = 0.20). The mean number of birds in the central peninsula with (2.27) and without (2.58) observations at phosphate mines was greater than in the other three regions (range of means: 1–2). Including or excluding observations at phosphate mines, the median number of Brown Pelicans has significantly increased throughout the interior of Florida since 1986 in comparison to observations before 1986 (Mann-Whitney U tests; including phosphate mines, U = 1138, P = 0.02; excluding phosphate mines, U = 797, $P < 0.01$). Except for one count of four birds in August, other counts of greater than two pelicans (n = 20) have occurred from December to June when birds also have been most frequently observed in the interior of Florida (Fig. 2). Within this broad peak, the seasonal distribution has shifted from winter and spring prior to 1986 to predominantly spring since 1986 (Fig. 3). Their seasonal distribution at phosphate mines did not affect these patterns. The number of pelicans per occurrence in the interior of Florida associated with tropical cyclones ranged from one to two birds (n = 6; 5% of total number) from June to November (1910 to 1996).

Counts of Royal Terns in the interior of Florida have reached 26 birds (at phosphate mines in Polk County). The number of birds at phosphate mines (median = 2, range = 1–26, n = 31) was significantly greater than the number away from phosphate mines, compared to either the whole of the interior of Florida (median = 1, range = 1–6, n = 38; U = 304, $P < 0.001$) or only within central Florida (median = 1, range = 1–6, n = 25; U = 219, P = 0.005). The sample away from phosphate mines within Polk County (median = 1, range = 1–3, n = 5) was too small to test. The mean number of birds at phosphate mines in Polk County (3.84) also was greater than in these three regions (range of means: 1.39–1.6). Excluding obser-

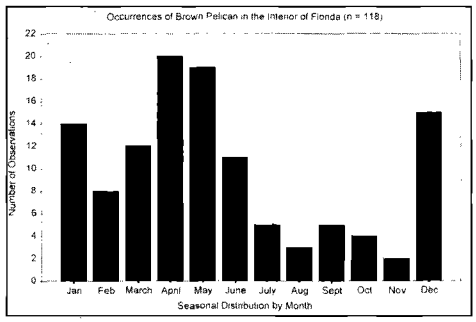

Figure 2. Number of observations of Brown Pelican from the interior of Florida by month for all years.

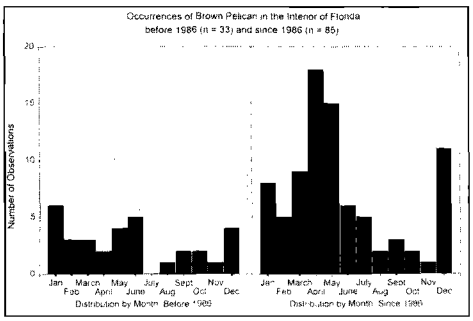

Figure 3. Number of observations of Brown Pelican from the interior of Florida by month before 1986 and since 1986.

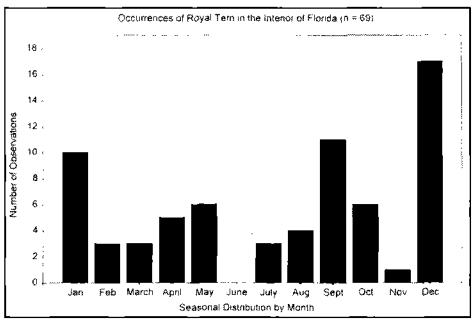

Figure 4. Number of observations of Royal Tern from the interior of Florida by month for all years.

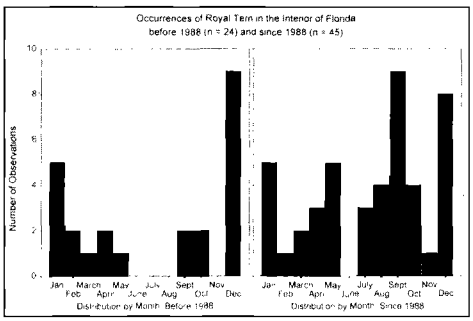

Figure 5. Number of observations of Royal Tern from the interior of Florida by month before 1988 and since 1988.

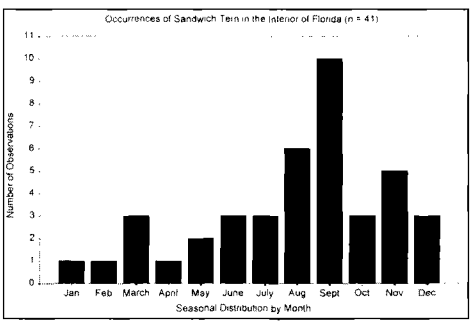

Figure 6. Number of observations of Sandwich Tern from the interior of Florida by month for all years.

vations at phosphate mines, the median number of Royal Terns in the interior of Florida was not significantly different among the Panhandle and the northern and central peninsula (Kruskal-Wallis test; $H = 1.36$, $P = 0.51$). Again excluding phosphate mines, the median number of Royal Terns in the interior of Florida since 1988 (median = 1, $n = 17$) was not significantly different than before 1988 (median = 1, $n = 21$; $U = 136.5$, $P > 0.20$). The mean numbers were 1.71 (since 1988) and 1.14 (before 1988). Except for two counts, other counts of greater than two birds (n = 14) have occurred from December through May which contain two of the three months (December, January) with the greatest number of observations (Fig 4). The peak of the seasonal distribution of Royal Terns has shifted however, from winter before 1988 to include spring (April–May) and autumn (July–October) since 1988 (Fig. 5). Observations at phosphate mines have contributed to the increase in spring and autumn Observations away from phosphate mines have contributed to the increase during autumn only. Two occurrences of a single Royal Tern (3% of total number) were associated with tropical cyclones in September.

Counts of Sandwich Terns in the interior of Florida have reached 554 birds (at phosphate mines in Polk County). The number of birds at phosphate mines (median = 16, range = 1–554, $n = 32$) was significantly greater than the number away from phosphate mines throughout the interior of Florida (median = 1, range = 1-2, $n = 9$, $U = 27$, $P < 0.001$). Except for two counts, counts of greater than 15 birds (n = 17) have occurred from late July to early December, when the number of observations (and number of birds) peaked in September (Fig. 6). Whereas Sandwich Terns have occurred in the interior of Florida throughout the year, the five occurrences (one or two birds) at and away from phosphate mines from January to March are from south and central Florida. Five occurrences (12% of total number) were associated with tropical cyclones. Three observations (all single birds) away from central Florida occurred in September Two counts (of 2 and 113 birds) in central Florida occurred at phosphate mines.

Recoveries of Banded Birds

Brown Pelicans and Royal Terns were two species that have been recovered within the interior of Florida since 1934 and 1930 respectively. Most of these recoveries were from the central and northern peninsula, none from phosphate mines; only one recovery of a Brown Pelican was from the Panhandle. Ten of 34 recoveries (29%) of Brown Pelicans were from the 1930s. Except for two recoveries since then, other recoveries have occurred since the 1970s (65%) Twenty-seven of 31 recoveries (87%) of Royal Terns have been since the 1970s, with 21 of these from the 1980s.

Most recoveries have involved immature or subadult Brown Pelicans ($n = 30$, 88%) and Royal Terns ($n = 27$, 87%). The first recoveries of adult Brown Pelicans and Royal Terns were in 1978 and 1982, respectively. Except for two rehabilitated pelicans and one Royal Tern of unknown age, other birds were originally banded as immatures. Most recoveries of immatures were direct recoveries of nestlings and juveniles. Brown Pelicans were originally banded on the Atlantic (North and South Carolina, Florida; $n = 20$) and Gulf (Louisiana, Florida; n = 3) Coasts. Royal Terns were recovered only from Atlantic Coast colonies in Virginia and the Carolinas.

Most recoveries for all age-classes of Brown Pelicans (75%) and Royal Terns (84%) occurred from December to March. One nestling Royal Tern (68481200) banded in Virginia on 2 July 1985 was recovered in northeast Polk County away from phosphate mines on 7 September 1985, which was exceptionally early. None of the recoveries for either Brown Pelicans or Royal Terns were associated with tropical cyclones.

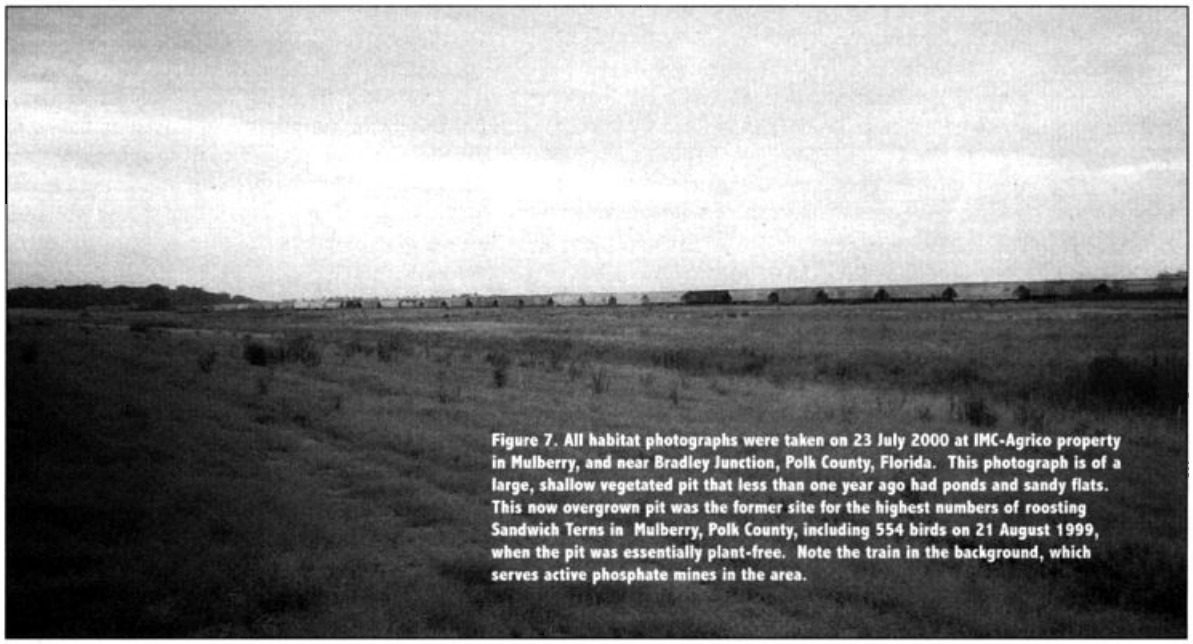

Figure 7. All habitat photographs were taken on 23 July 2000 at IMC-Agrico property in Mulberry, and near Bradley Junction, Polk County, Florida. This photograph is of a large, shallow vegetated pit that less than one year ago had ponds and sandy flats. This now overgrown pit was the former site for the highest numbers of roosting Sandwich Terns in Mulberry, Polk County, including 554 birds on 21 August 1999, when the pit was essentially plant-free. Note the train in the background, which serves active phosphate mines in the area.

DISCUSSION

Observer and habitat biases that contributed to the concentration of observations of the three marine-estuarine species in the interior of the central peninsula of Florida are similar to those for Magnificent Frigatebird (although frigatebirds do not land on water; see McNair 2000b), except for the number and proportion of observations at phosphate mines, especially for Royal and Sandwich Terns.

The different timing in the development of the phosphate-mining industry in the central and northern peninsula had no apparent effect on the occurrence of marine-estuarine birds in the interior of Florida. The first confirmed occurrences of Brown Pelican and Royal and Sandwich Terns on large clay settling ponds and other open-water habitats at phosphate mines in the central peninsula were not until the early to mid-1980s (this study; although a few unspecified observations may have occurred in the 1970s, cf. Layne et al. 1977), one decade after phosphate mining began in the northern peninsula. Access to phosphate mines in central Florida has improved since 1982 (C. Geanangel pers. comm.) when other rare to uncommon waterbirds have been reported (Fellers 1989, Palmer 1991, Paul et al. 1994). However, the prior absence of observations of the three marine-estuarine birds at phosphate mines probably cannot be attributed to a lack of observer effort (despite the post-1980 restriction of observations to Polk County), although observer effort has greatly increased throughout the interior of Florida (for observational and recovery data) since the 1970s (McNair 2000b, this study). O. Baynard found an active nest of the Black-necked Stilt *Himantopus mexicanus* in an old phosphate mine near Plant City, Hillsborough County as early as 1931 (Howell 1932), after draglines were introduced. When the number and size of clay settling ponds expanded, Gull-billed and Least Terns began breeding at phosphate mines as early as the mid-1960s (TTRS archives). In addition, Maehr (1984) documented the occurrence of other larids and American White Pelican *P. erythrorhynchos* at phosphate mines in central Florida, yet no Brown Pelicans or Royal and Sandwich Terns. Brown Pelicans were not observed at Saddle Creek park until the 1990s (when single birds were recorded on three occasions in spring), despite public access and observer coverage since the early 1960s. Furthermore, the absence of counts greater than two birds for any of the three marine-estuarine species from anywhere in the interior of Florida (including phosphate mines) until the mid- to late 1980s, and the magnitude of the counts for Royal and Sandwich Terns (mainly the latter species) at phosphate mines in Polk County since then suggests the increase is real and not an artifact of an increase of observer effort in specialized habitat.

Although much smaller, the phosphate-mining industry in the northern peninsula contains fairly large (28–288 ha) active and inactive settling ponds (Wenner and Marion 1981, Maehr and Marion 1986) where Brown Pelicans and Royal and Sandwich Terns have never been observed. These marine-estuarine birds have not been overlooked because many investigators have conducted scientific studies in large retention ponds at northern phosphate mines (mainly Hamilton County) over the last several decades (Marion et al. 1981, Wenner and Marion 1981, O'Meara et al. 1985, Myers et al. 1989). Other rare waterbirds have been reported there in all seasons (Repenning and Wester 1978, Stafford 1979, Maehr 1981, 1984, Maehr et al. 1984, Woolfenden and Woolfenden 1984, Maehr and Marion 1986, Bergstrom 1999), including a breeding population of Least Terns (Maehr 1982). Thus, absence of the three coastal species from phosphate mines in the northern peninsula is real and not an artifact of observer effort.

Unlike the northern peninsula, the Lake District of central Florida provides a water-dominated landscape for east-west movements of marine-estuarine birds to phosphate mines in the interior. However, with or without phosphate mines, marine-estuarine birds that rarely occur in the interior of Florida have been concentrated in the Lake District of the central peninsula (and Lake Okeechobee; cf. McNair 2000a). Although the Lake District narrowly extends up the central sandy ridge to the northern peninsula where observers are concentrated in Alachua County (where east-west movements are not impeded by the peninsular base which is located further north along the Georgia border), relatively few marine-estuarine birds have occurred in the northern peninsula or in other regions of Florida outside the Lake District. The Lake District also concentrates other marine-estuarine birds that normally do occur in the interior of Florida (Robertson and Woolfenden 1992, Stevenson and Anderson 1994). This includes such understudied phenomenon as the nocturnal foraging and bathing of Black Skimmers along shores of lakes during winter, which formerly required daily movements of birds from the coast (Nicholson 1948) before establishment of large winter populations (Robertson and Woolfenden 1992, Stevenson and

Anderson 1994).

Despite the influence of the Lake District on the movement of marine-estuarine birds to the interior of the central peninsula (see above and the introduction), the increase of Royal and Sandwich Terns in the interior of Florida has been restricted to phosphate mines since the mid- to late 1980s, unlike Brown Pelican which does not rely on phosphate mines yet has increased throughout the interior of Florida. This suggests that habitat features at phosphate mines may account in part for this difference in comparative use among the three species (see Figs. 7-10), and not other factors such as distance from the coast (50-65 km). The terns forage at large diked early to mid-successional clay settling ponds (not late successional ponds which are dominated by marsh), less frequently at the two other open-water habitats. They may roost on barren shorelines at these ponds with many other larids (e.g., Caspian *S. caspia* and Black *Chlidonias niger* Terns, Black Skimmer; C. Geanangel unpubl. data), on sandy spits that are relatively free from disturbance, or on nearby sandy flats associated with pools. Royal and Sandwich Terns may remain overnight at phosphate mines or return to the coast. Regardless, both terns have directed movements to phosphate mines, which this study has undoubtedly greatly undersampled. A systematic sampling scheme would greatly improve our knowledge of their movements and uses of phosphate mines. This movement is especially remarkable for Sandwich Terns, because numbers in autumn can be so large yet Sandwich Terns remain rare in the interior of Florida away from phosphate mines. In contrast, movements of individuals of both species to the central peninsula away from phosphate mines and to the interior of other regions of Florida still appear to represent disoriented immatures, which recovery data for Royal Tern has confirmed.

An assessment of the status of breeding populations of Royal Terns in the Southeast since Clapp and Buckley (1984) is not available. However, an increase of Tampa Bay breeding populations (Egensteiner et al. 1996) and the seasonal shift in distribution of birds in the interior of Florida to include spring and autumn (at phosphate mines; other birds elsewhere in the interior of Florida only shifted during autumn) suggest that local coastal birds may now occur inland outside the breeding season and augment the number of northern birds. However, apparent directed movement of Royal Terns to phosphate mines in the central peninsula may instead represent northern birds that are migrating, although the number of birds is low. The origin of these birds requires confirmation. Before the late 1980s, the sharp peak of observations in December and January of Royal Terns corresponded to the timing of recoveries in the interior of Florida of banded birds that fledged from breeding colonies on the Atlantic coast from Virginia to South Carolina (Lohrer 1984, this study). In addition, Smith et al. (1994) documented that banded Royal Terns salvaged over winter on the coast of central Florida were almost entirely from northern breeding populations.

Breeding populations of Sandwich Tern have increased locally (central Gulf coast of Florida) since the mid-1980s (Rodgers et al. 1996), but the recent increase of breeding populations elsewhere in Florida has been modest (McNair and Gore 1999). Unlike Royal Terns, most Sandwich Terns occur in the interior of Florida only in late summer and autumn. The timing and magnitude of some counts (up to 544 birds) suggest that post-breeding individuals from more westerly or northerly populations are involved. The large numbers also suggest a Gulf and not Atlantic origin for the birds (Clapp and Buckley 1984), and the phosphate mines themselves are located closer to the Gulf than to the Atlantic Coast. Compared to Sandwich Terns in autumn, few Royal Terns use phosphate mines even though coastal breeding populations in central Florida are higher. This also suggests that local Sandwich Terns may be scarce at phosphate mines in autumn, although adults feeding juveniles have been present as early as late July. The scarcity of Sandwich Terns from the interior of Florida in April and May, in conjunction with low numbers along the coast during this period (Clapp et al. 1983), suggests that many birds migrate offshore during spring. Winter occurrences in the interior are few (cf. Woolfenden 1973), even if removed reports are included (e.g., Sullivan 1986), because most Sandwich Terns winter south of Florida.

Including or excluding phosphate mines of the central peninsula, only the Brown Pelican has modestly increased in abundance throughout the interior of Florida since the mid-1980s, except for the much larger increase at Lake Okeechobee (Smith and Goguen 1993). This suggests that the increase in frequency of occurrence outside Lake Okeechobee is also real, not an artifact of an increase in observer effort. Smith and Goguen (1993) attributed the increase of Brown Pelicans in the interior of Florida, including Lake Okeechobee where

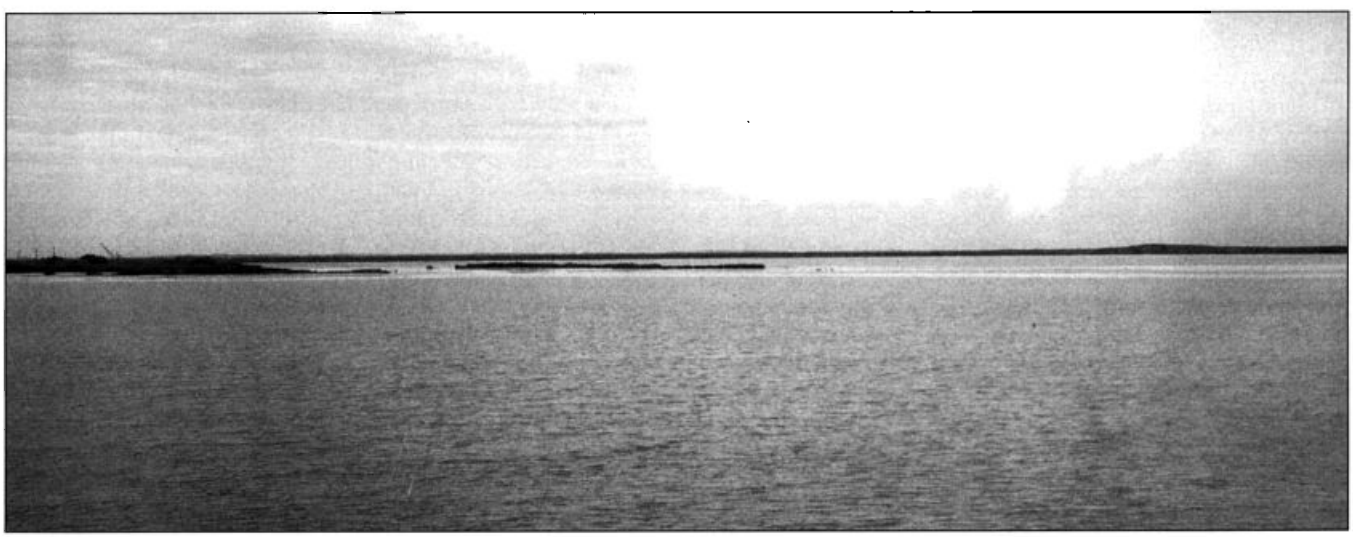

Figure 8. A large, diked, raised active clay settling pond at Kingsford Mines off Doc Durrance Road, ±4 km west of Bradley Junction. This view looks across the impoundment locally named the "Big Pit" toward a sandy flat interspersed with marsh encroaching into the open water. The expansive landscape is typical of such large impoundments where larids, including Royal and Sandwich Terns, forage in the open water. The "Big Pit" and other active impoundments are encircled by firm dirt roads on top of dikes that are easily traveled in dry weather and that provide good opportunities for viewing birds, although permission must be obtained to enter the property.

Figure 9. A closer view of the sandy flat interspersed with marsh encroaching into open water at the "Big Pit." This flat is a favored roosting site for larids, including Royal and Sandwich Terns. Both species were present on this date, including adult Sandwich Terns feeding fish to dependent juveniles approximately three weeks post-fledgling.

as many as 60–70 birds in a flock were present from late winter into summer in the late 1980s, to the increase of coastal populations in Florida that peaked in the late 1980s (Nesbitt 1996). Coastal populations of Brown Pelicans in the Southeast outside Florida also have increased dramatically during the last two decades (Wilkinson et al. 1994). Banding data confirm that in-state and out-of-state sources are responsible for the increase of Brown Pelicans in the interior of Florida, which preceded the breeding-range expansion to Lake Okeechobee in 1991 (Smith and Goguen 1993) although this small pioneering population has not persisted. This suggests that population increases in source areas, and not habitat loss on the coast or habitat change in the interior where birds have primarily occurred at large natural lakes, are responsible for the increase of Brown Pelicans in the interior of Florida. Local breeding populations in south and central Florida (Florida Bay and Tampa Bay) have decreased (see Nesbitt 1996), although statewide populations are still large.

Despite their increase throughout the interior of Florida, the relative scarcity of Brown Pelicans at phosphate mines in the central peninsula probably can be attributed to less favorable habitat. Larger fish that are suitable prey for this plunge-diving piscivorous species may be scarce at clay settling ponds in comparison to prey available in natural freshwater lakes. Double-crested Cormorants *Phalacrocorax auritus* foraging at settling ponds on phosphate mines relied upon small invertebrates as well as small fish (mainly mosquito-fish *Gambusia affinis*), which is unusual (O'Meara et al. 1982). Larger fish were apparently limited for the much smaller piscivorous cormorant. Brown Pelicans also occur on unreclaimed phosphate pits with lakes and reclaimed areas (e.g., Saddle Creek park), but these birds rarely linger there either.

The broad peak of occurrence of Brown Pelicans throughout the interior of Florida remains December through June (Smith and Goguen 1993, this study). However, the seasonal shift from winter to spring since the mid-1980s, based on observational data, indicates that proportionally fewer birds now occur during winter, although recovery data are still predominantly from winter (suggesting higher mortality during this season, at least for immature birds). Other than the shift in timing of occurrence, pelicans are also staying longer (at Lake Okeechobee, Smith and Goguen 1993; away from Lake Okeechobee at natural lakes in the central peninsula where up to four birds have roosted at the same locality for longer than six months, C. Geanangel unpubl. data). A few of these birds have become habituated to handouts of food (C. Geanangel unpubl. data, cf. Laughing Gulls at landfills). Adult pelicans now also occur away from Lake Okeechobee in the interior (first recovery of banded bird in 1978; first observation in 1983), although most pelicans in the interior are immatures (Robertson and Woolfenden

Figure 10. A water-treatment pond adjacent to and below the "Big Pit." The pond serves the active phosphate mine processing-plant in the background. Many terns forage on this pond, including Royal and Sandwich. Terns do not roost here because the pond lacks sandy shorelines.

1992, Nesbitt 1996, this study). These changes suggest that dispersal behavior is developing into more of a pattern of periodic migration of adults rather than just disoriented movements of immatures, especially in spring which corresponds to the breeding season of Brown Pelicans in central and northern Florida.

Nonetheless, most movements of Brown Pelicans into the interior of Florida (excluding Lake Okeechobee) have involved immatures. In the 1930s, banding recoveries of immature Brown Pelicans from the interior of Florida revealed that these birds were from one colony on the central Atlantic coast of Florida (Longstreet and Davis 1936, Longstreet 1945, this study). Subsequent recoveries from the interior also have confirmed that immatures arrive directly from the Gulf Coast, despite the fact that Brown Pelicans from the Atlantic Coast of Florida are generally more migratory than birds along the Gulf Coast (Schreiber and Mock 1988). Carolina-fledged birds also winter both on the Atlantic Coast and in the interior of Florida (Smith and Goguen 1993, Nesbitt 1996, this study). Banding data are biased toward recoveries in the interior of Florida of birds banded as nestlings or fledglings on the Atlantic Coast, as few adults are banded. The considerable variation in the timing of breeding in south and central Florida (winter-spring cycle with some irregularity) compared to the remainder of its range in the Southeast (spring-summer cycle only; Schreiber 1980), and the equivocal and biased evidence from banding recoveries, prevent a more detailed assessment of source populations for Brown Pelicans in the interior of Florida.

Tropical cyclones had a minor impact on observations of three marine-estuarine species in the interior of Florida except for Sandwich Terns away from central Florida, unlike the occurrence of Royal and Sandwich Terns in the interior of southeastern North America north of Florida during some tropical cyclones (Fussell and Allen-Grimes 1980, LeGrand 1990, Brinkley et al. 1997, Brinkley 1999). This difference suggests that some marine-estuarine and other marine species may be undersampled in the interior of Florida during tropical cyclones (McNair unpubl. data). The 113 Sandwich Terns associated with a tropical cyclone can be discounted because it is probably an artifact of coincidence; these birds would have roosted on sandbars among open-water in shallow, abandoned phosphate pits in Polk County since large numbers also roosted at this site on other dates during that autumn (C. Geanangel pers. comm.).

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